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High-Current, Cold-Cathode Discharge Sources for Ion Implantation

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We are developing reliable, high-efficiency, high-power ion sources that are applicable to a broad class of material-surface modification processes (e.g., the production of wear- and corrosion-resistant metals and polymers). The reverse magnetron, a plasma configuration invented at the Institute of Electrophysics in Yekaterinburg, Russia, is a high-current glow discharge with a cold cathode in crossed electric and magnetic fields. Prototype ion sources of ~150 cm^2 have been constructed that have operated successfully and reliably at 50 mA and 40 keV in reactive gases. Our program is directed toward developing a 1000-cm^2 source, with emphasis on (1) studying ignition and stable-discharge operation under low gas pressures with high currents; (2) optimizing conditions for formation of the ion-plasma emitter that produces a high ion current density with uniformity over a large area; and (3) decreasing contaminants generated by cathode erosion. Ion-implantation experiments were performed with carbon, nitrogen, and oxygen ions implanted into stainless steel over a wide range of temperatures and current densities. Significant increases in the surface hardness were observed in carbon and nitrogen implants, with the best results at intermediate temperatures of 400–500°C, resulting in case depths of 5–10 times the ballistic ion ranges. Improvements in wear of up to 100 times were observed.

Materials Processing with Intense, Pulsed Ion Beams

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Intense, pulsed ion beams (IPIBs) are an emerging technology that has been developed throughout the world over the last two decades, primarily for nuclear-fusion and high-energy-density physics research. IPIBs are created in magnetically insulated vacuum diodes from which 10- to 1000-kA beams of low-Z ions are accelerated to energies typically between 10 keV and 10 MeV in 10- to 1000-ns pulses. Physics Division is collaborating with two Russian institutes to develop IPIBs for the surface treatment of materials. The short range (0.1–10 μm) and high energy density (1–50 J/cm^2) of these short-pulsed beams make them ideal for flash-heating a target surface in a way that is similar to the more familiar pulsed laser processes. IPIB surface treatment induces rapid melt and solidification at up to 10^{10} K/s, which causes amorphous layer formation and the production of nonequilibrium microstructures. On the Anaconda accelerator at LANL, a 300-keV, 30-kA, 1-μs intense beam of carbon, oxygen, and hydrogen ions is used for the surface treatment of AISI-4620 steel, a common material used in automotive gear applications. Treated surfaces are up to 1.8 times harder than untreated surfaces and have no discernible change in modulus over depths of 1 μm or more. Qualitative improvements in the wear morphology of treated surfaces are observed.